



### **Science Arts & Métiers (SAM)**

is an open access repository that collects the work of Arts et Métiers Institute of Technology researchers and makes it freely available over the web where possible.

This is an author-deposited version published in: <https://sam.ensam.eu>  
Handle ID: <http://hdl.handle.net/10985/19565>



This document is available under CC BY license

#### **To cite this version :**

Dorian DEPRIESTER, Régis KUBLER - MTEX2Gmsh: a tool for generating 2D meshes from EBSD data - Journal of Open Source Software - Vol. 5, n°52, p.2094 - 2020

Any correspondence concerning this service should be sent to the repository

Administrator : [scienceouverte@ensam.eu](mailto:scienceouverte@ensam.eu)






# MTEX2Gmsh: a tool for generating 2D meshes from EBSD data

Dorian Depriester<sup>1</sup> and Régis Kubler<sup>1</sup>

<sup>1</sup> MSMP laboratory (EA 7350), Ecole Nationale Supérieure d'Arts et Métiers, 2 cours des Arts et Métiers - 13617 Aix-en-Provence, France

DOI: [10.21105/joss.02094](https://doi.org/10.21105/joss.02094)

## Software

- [Review](#) 
- [Repository](#) 
- [Archive](#) 

Editor: [Marie E. Rognes](#) 

## Reviewers:

- [@streeve](#)
- [@ralfHielscher](#)

Submitted: 16 December 2019

Published: 22 August 2020

## License

Authors of papers retain copyright and release the work under a Creative Commons Attribution 4.0 International License ([CC BY 4.0](#)).

## Summary

In material sciences applied to crystalline materials, such as metals or ceramics, the grain morphology (size and shape) and the crystallographic texture are of great importance for understanding the macroscopic behaviour of the materials. Micromechanics of polycrystalline aggregates consists in evaluating the thermo-mechanical behaviour of the aggregates at their grain scale. If the investigated material is subjected to macroscopic deformation, the local strain can be obtained either experimentally, thanks to full-field measurement methods such as microgrid technique (Allais, Bornert, Bretheau, & Caldemaison, 1994) or Digital Image Correlation (DIC) (Hild, Raka, Baudequin, Roux, & Cantelaube, 2002), or thanks to numerical simulation of the microstructure. The latter needs to take into account the mechanical heterogeneities (due to the different constituents) and the anisotropy of each phase, depending on its crystalline orientation.

Orientation Imaging Microscopy (OIM), usually made from Electron Backscatter Diffraction (EBSD), is now widely used as a characterization technique. Indeed, it is in great interest for investigating the grain morphology and local crystal orientations in crystalline materials. Raw EBSD data can be considered as matrices of measurements of crystallographic data: each dot contains information about the phase and its orientation at the corresponding position.

In order to perform Finite Element Analysis (FEA) on a polycrystal, one needs to first generate a mesh based on either EBSD or reconstructed grains. In this mesh, the Grain Boundaries (GBs) must be accurately described since they play an important role in the overall behaviour of aggregates. Indeed, it is known that GBs increase the energy of the materials. The interfacial energy between two adjacent grains due to their boundary depends, among other parameters, on their misorientation and on the surface normal of the boundary (Priester, 2012). In addition, Zhong, Rowenhorst, Beladi, & Rohrer (2017) mentioned that the GB curvature is one of the most important properties of a microstructure. For instance, the driving force for grain growth depends on the local curvature of the GBs.

Latypov, Shin, De Cooman, & Kim (2016) proposed a program to generate regular pseudo-3D mesh, consisting in brick elements with only one element in thickness. Nevertheless, this program results in serrated descriptions of the GBs because of the regular structure of EBSD data. In addition, the element size must be constant, possibly resulting in a huge number of elements, depending on the size and the spatial resolution of the orientation map. Dancette, Browet, Martin, Willemet, & Delannay (2016) proposed the following method to generate a conforming mesh with smooth GBs:

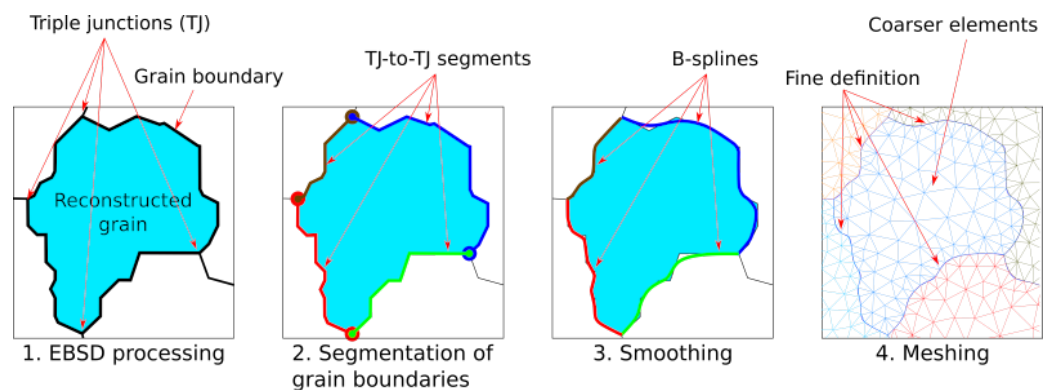
- computation of the GBs based on a proper criterion;
- grain reconstruction using a graph theory-based method;
- spline interpolation of the GBs;
- meshing.

The criterion used by the previous authors for defining the GBs, called weight in the context of graph theory, was specially designed for cubic phases. The geometry was meshed using the Gmsh software (Geuzaine & Remacle, 2009).

As a conclusion, it appears that no existing tool for generating meshes from EBSD data is able to provide a robust grain description (e.g. suitable for any kind of phase and geometry) together with customizable features (e.g. variable element sizes). The proposed software, named **MTEX2Gmsh** works regardless the number of phases and the symmetries of those phases. In addition, it provides a smooth and accurate definition of the GBs. It is based on the MTEX toolbox for Matlab (Bachmann, Hielscher, & Schaeben, 2011) and the Gmsh software. Figure 1 schematically illustrates the proposed algorithm. **MTEX2Gmsh** allows to mesh the volume with a couple of options, such as:

- increasing element size with increasing distance from the grains boundaries;
- element type (tetrahedron, wedge or brick elements);
- nesting the Region of Interest (ROI) into a larger medium.

This software comes with an Abaqus plugin for importing the mesh and allocating the phase and Euler Angles of each grain.



**Figure 1:** Schematic representation of the algorithm used in MTEX2Gmsh: 1) once the grains are reconstructed using to MTEX (Bachmann et al., 2011), the algorithm fetches all triple junctions (TJ) in the whole map; 2) each grain boundary is divided into TJ-to-TJ segments; 3) all those segments are smoothed using B-spline approximation; 3) this descriptions of the grains can be converted into Gmsh-readable files (Geuzaine & Remacle, 2009), allowing to mesh the whole region efficiently. The B-spline approximation results in very accurate definitions of the GBs, with limited serration (usually introduced by the EBSD resolution) and limited number of elements.

## References

- Allais, L., Bornert, M., Bretheau, T., & Caldemaison, D. (1994). Experimental characterization of the local strain field in a heterogeneous elastoplastic material. *Acta Metallurgica et materialia*, 42(11), 3865–3880. doi:[10.1016/0956-7151\(94\)90452-9](https://doi.org/10.1016/0956-7151(94)90452-9)
- Bachmann, F., Hielscher, R., & Schaeben, H. (2011). Grain detection from 2d and 3d ebsd data—specification of the mtex algorithm. *Ultramicroscopy*, 111(12), 1720–1733. doi:[10.1016/j.ultramic.2011.08.002](https://doi.org/10.1016/j.ultramic.2011.08.002)
- Dancette, S., Browet, A., Martin, G., Willemet, M., & Delannay, L. (2016). Automatic processing of an orientation map into a finite element mesh that conforms to grain boundaries. *Modelling and Simulation in Materials Science and Engineering*, 24(5), 055014. doi:[10.1088/0965-0393/24/5/055014](https://doi.org/10.1088/0965-0393/24/5/055014)

- Geuzaine, C., & Remacle, J.-F. (2009). Gmsh: A 3-D finite element mesh generator with built-in pre-and post-processing facilities. *International journal for numerical methods in engineering*, 79(11), 1309–1331. doi:[10.1002/nme.2579](https://doi.org/10.1002/nme.2579)
- Hild, F., Raka, B., Baudequin, M., Roux, S., & Cantelaube, F. (2002). Multiscale displacement field measurements of compressed mineral-wool samples by digital image correlation. *Appl. Opt.*, 41(32), 6815–6828. doi:[10.1364/AO.41.006815](https://doi.org/10.1364/AO.41.006815)
- Latypov, M. I., Shin, S., De Cooman, B. C., & Kim, H. S. (2016). Micromechanical finite element analysis of strain partitioning in multiphase medium manganese TWIP+TRIP steel. *Acta Materialia*, 108, 219–228. doi:[10.1016/j.actamat.2016.02.001](https://doi.org/10.1016/j.actamat.2016.02.001)
- Priester, L. (2012). *Grain boundaries: From theory to engineering* (Vol. 172). Springer Science & Business Media.
- Zhong, X., Rowenhorst, D. J., Beladi, H., & Rohrer, G. S. (2017). The five-parameter grain boundary curvature distribution in an austenitic and ferritic steel. *Acta Materialia*, 123, 136–145. doi:[10.1016/j.actamat.2016.10.030](https://doi.org/10.1016/j.actamat.2016.10.030)